

U. S. DEPARTMENT OF COMMERCE

BUILDING
MATERIALS
AND
STRUCTURES

REPORT BMS93

Accumulation of Moisture in
Walls of Frame Construction
During Winter Exposure

by

CHARLES G. WEBER

and ROBERT C. REICHEL

NATIONAL
BUREAU OF STANDARDS



BUILDING MATERIALS AND STRUCTURES REPORTS

On request, the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C., will place your name on a special mailing list to receive notices of new reports in this series as soon as they are issued. There will be no charge for receiving such notices.

An alternative method is to deposit with the Superintendent of Documents the sum of \$5, with the request that the reports be sent to you as soon as issued, and that the cost thereof be charged against your deposit. This will provide for the mailing of the publications without delay. You will be notified when the amount of your deposit has become exhausted.

If 100 copies or more of any report are ordered at one time, a discount of 25 percent is allowed. Send all orders and remittances to the *Superintendent of Documents, U. S. Government Printing Office, Washington, D. C.*

The following publications in this series are available by purchase from the Superintendent of Documents at the prices indicated:

BMS1	Research on Building Materials and Structures for Use in Low-Cost Housing.....	10¢
BMS2	Methods of Determining the Structural Properties of Low-Cost House Constructions....	10¢
BMS3	Suitability of Fiber Insulating Lath as a Plaster Base.....	10¢
BMS4	Accelerated Aging of Fiber Building Boards.....	10¢
BMS5	Structural Properties of Six Masonry Wall Constructions.....	15¢
BMS6	Survey of Roofing Materials in the Southeastern States.....	15¢
BMS7	Water Permeability of Masonry Walls.....	10¢
BMS8	Methods of Investigation of Surface Treatment for Corrosion Protection of Steel.....	10¢
BMS9	Structural Properties of the Insulated Steel Construction Co.'s "Frameless-Steel" Constructions for Walls, Partitions, Floors, and Roofs.....	10¢
BMS10	Structural Properties of One of the "Keystone Beam Steel Floor" Constructions Sponsored by the H. H. Robertson Co.....	10¢
BMS11	Structural Properties of the Curren Fabrihome Corporation's "Fabrihome" Constructions for Walls and Partitions.....	10¢
BMS12	Structural Properties of "Steelox" Constructions for Walls, Partitions, Floors, and Roofs Sponsored by Steel Buildings, Inc.....	15¢
BMS13	Properties of Some Fiber Building Boards of Current Manufacture.....	10¢
BMS14	Indentation and Recovery of Low-Cost Floor Coverings.....	10¢
BMS15	Structural Properties of "Wheeling Long-Span Steel Floor" Construction Sponsored by the Wheeling Corrugating Co.....	10¢
BMS16	Structural Properties of a "Tilecrete" Floor Construction Sponsored by Tilecrete Floors, Inc.....	10¢
BMS17	Sound Insulation of Wall and Floor Constructions.....	10¢
	Supplement to BMS 17, Sound Insulation of Wall and Floor Constructions.....	5¢
BMS18	Structural Properties of "Pre-fab" Constructions for Walls, Partitions, and Floors Sponsored by the Harnischfeger Corporation.....	10¢
BMS19	Preparation and Revision of Building Codes.....	15¢
BMS20	Structural Properties of "Twachtman" Constructions for Walls and Floors Sponsored by Connecticut Pre-Cast Buildings Corporation.....	10¢
BMS21	Structural Properties of a Concrete-Block Cavity-Wall Construction Sponsored by the National Concrete Masonry Association.....	10¢
BMS22	Structural Properties of "Dun-Ti-Stone" Wall Construction Sponsored by the W. E. Dunn Manufacturing Co.....	10¢
BMS23	Structural Properties of a Brick Cavity-Wall Construction Sponsored by the Brick Manufacturers Association of New York, Inc.....	10¢
BMS24	Structural Properties of a Reinforced-Brick Wall Construction and a Brick-Tile Cavity-Wall Construction Sponsored by the Structural Clay Products Institute.....	10¢
BMS25	Structural Properties of Conventional Wood-Frame Constructions for Walls, Partitions, Floors, and Roofs.....	15¢
BMS26	Structural Properties of "Nelson Pre-Cast Concrete Foundation" Wall Construction Sponsored by the Nelson Cement Stone Co., Inc.....	10¢
BMS27	Structural Properties of "Bender Steel Home" Wall Construction Sponsored by the Bender Body Co.....	10¢
BMS28	Backflow Prevention in Over-Rim Water Supplies.....	10¢
BMS29	Survey of Roofing Materials in the Northeastern States.....	10¢
BMS30	Structural Properties of a Wood-Frame Wall Construction Sponsored by the Douglas Fir Plywood Association.....	10¢
BMS31	Structural Properties of "Insulite" Wall and "Insulite" Partition Constructions Sponsored by The Insulite Co.....	15¢

[List continued on cover page III]

UNITED STATES DEPARTMENT OF COMMERCE • Jesse H. Jones, Secretary
NATIONAL BUREAU OF STANDARDS • Lyman J. Briggs, Director

BUILDING MATERIALS *and* STRUCTURES

REPORT BMS93

Accumulation of Moisture in Walls of Frame
Construction During Winter Exposure

by

CHARLES G. WEBER *and* ROBERT C. REICHEL



ISSUED NOVEMBER 4, 1942

The National Bureau of Standards is a fact-finding organization;
it does not "approve" any particular material or method of construction. The technical findings in this series of reports are to
be construed accordingly.

UNITED STATES GOVERNMENT PRINTING OFFICE • WASHINGTON • 1942

FOR SALE BY THE SUPERINTENDENT OF DOCUMENTS, WASHINGTON, D. C. • PRICE 10 CENTS

Foreword

This report presents data on the actual accumulation of moisture in full-height sections of the north outside wall of a frame house during winter weather. Seven different constructions were included, and wood sheathing and fiber sheathing were used in direct comparison. The results appear to be of practical interest in modern house design.

LYMAN J. BRIGGS, *Director.*

Accumulation of Moisture in Walls of Frame Construction During Winter Exposure

by CHARLES G. WEBER and ROBERT C. REICHEL

CONTENTS

	Page		Page
Foreword.....	ii	IV. Performance of test walls.....	4
I. Introduction.....	1	V. Summary and conclusions.....	5
II. Description of wall sections tested.....	2	VI. References.....	5
III. Testing procedure.....	2		

ABSTRACT

The condensation and accumulation of moisture in outside walls of frame construction were observed during winter weather in Washington, D. C. Seven different constructions were exposed simultaneously as adjacent full-height sections of the north wall of a frame structure. The humidity and temperature of the inside air were controlled to produce an average vapor-pressure drop across the wall of approximately 0.2 pound per square inch. Use of a good vapor barrier on the warm side of the wall prevented condensation. In every instance where no vapor barrier was used on the warm side of the wall, condensation occurred within the wall. The use of a vapor barrier on the cold side of the wall increased the accumulation of moisture. The performance of walls of standard wood construction was not basically different from those containing fiber sheathing boards.

I. INTRODUCTION

The accumulation of moisture within the outside walls of houses during winter weather has received much attention recently. It is not a new problem, but rather an old one that has come to the front most emphatically since the practice of humidification in homes has become widespread. Newly developed methods of adding moisture to the air by so-called air-conditioning heating units have produced conditions that are conducive to the condensation of moisture within walls unless adequate measures are taken to pre-

vent vapor from entering from the warm sides. The problem of condensation has also become more acute with the widespread use of insulation even without deliberate humidification.

Considerable investigative work has been done on the problem in general, and numerous articles have been published on the subject. Woolley [1]¹ discussed the theory of condensation in walls, and Teesdale [2] and Rowley [3, 4] published excellent data on vapor transmission of materials, condensation of moisture in various types of walls, and on methods of preventing condensation. However, there have been instances of unexplained condensation in walls, some of which have been attributed to the use of the relatively new material, fiber sheathing.

This investigation was made for the purpose of obtaining some basic information on the accumulation of moisture in the outside walls of frame construction, using fiber sheathing and wood sheathing in direct comparison. To accomplish this, full-scale wall sections of various constructions were placed in the north wall of a test house on the Bureau grounds. Their performance was observed during winter weather while relatively high humidity and temperature were maintained within the structure.

¹ Numbers in brackets indicate the literature references at the end of this paper.

II. DESCRIPTION OF WALL SECTIONS TESTED

Seven wall sections were tested, each representing a specific type of frame construction. The constructions of the various sections were as follows:

Section *A*, shown in figure 1, consisted of 2-by 4-inch studding with $\frac{1}{2}$ -inch insulation wallboard nailed to the inside and $2\frac{5}{32}$ -inch fiber sheathing board nailed to the outside. The

section *A* except that no vapor barrier was included.

Section *D* was the same as section *C* except that an asphalt duplex sheathing paper of good quality was placed on the outside of the sheathing, under the siding.

Section *E* was exactly like section *D* except that ordinary sheathing of southern yellow pine wood was used instead of the fiber sheathing boards.

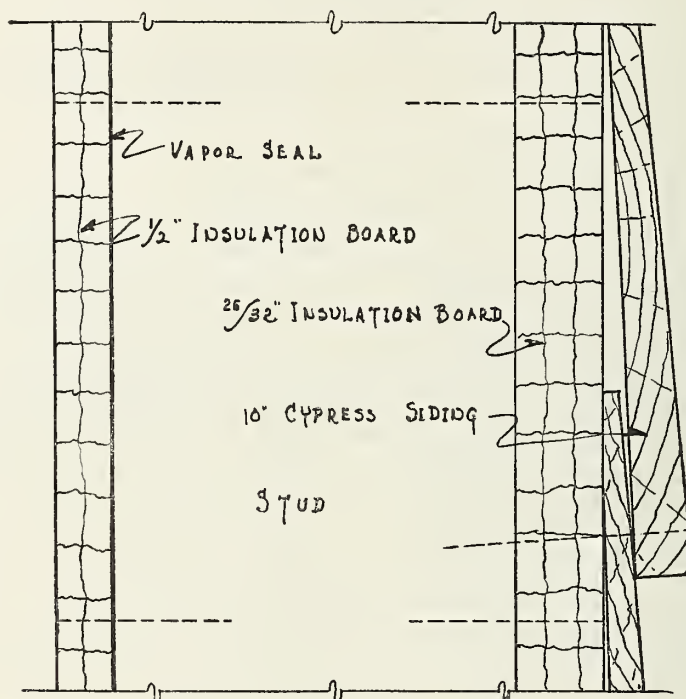


FIGURE 1.—Section of test panel *A*.

outside of the sheathing was covered with 10-inch cypress siding lapped 3 inches. The siding was painted on the outside with one coat of primer and two coats of outside white paint. A vapor barrier consisting of a 2-ounce copper foil bonded with asphalt to a backing of kraft paper was placed immediately under the wallboard on the inside of the studding, with all joints lapped 4 inches.

Section *B* was the same as section *A* except that the copper-foil vapor barrier was on the outside of the stud space, under the sheathing.

Section *C* was of the same construction as

Section *F* differed from section *E* only in that a vapor barrier of copper foil paper was placed against the inside surface of the sheathing.

Section *G* was the same as section *F* except that the copper foil barrier was placed on the warm side of the air space, between the wallboard and the studs, as in section *A*.

III. TESTING PROCEDURE

The performance of the various sections was observed for a period of 14 days in midwinter. During this time the humidity and temperature inside the house were controlled. The air

temperature on the inside, or warm side of the wall, at approximately the breathing level, was 75° F during the day, and it was allowed to drop to 60° F during the night, the mean for the test period being 71° F. A mean relative humidity of approximately 70 percent was maintained. The average outdoor temperature for the period was 28° F. Hence, the

wall at approximately breathing level and at 10 inches above the floor level. Temperatures were measured with the use of Chromel-Alumel thermocouples and a suitable potentiometer. Moisture data were obtained by checking the weights of specimens of photographic blotting paper of known relative-humidity-moisture-content relationship. The location of the

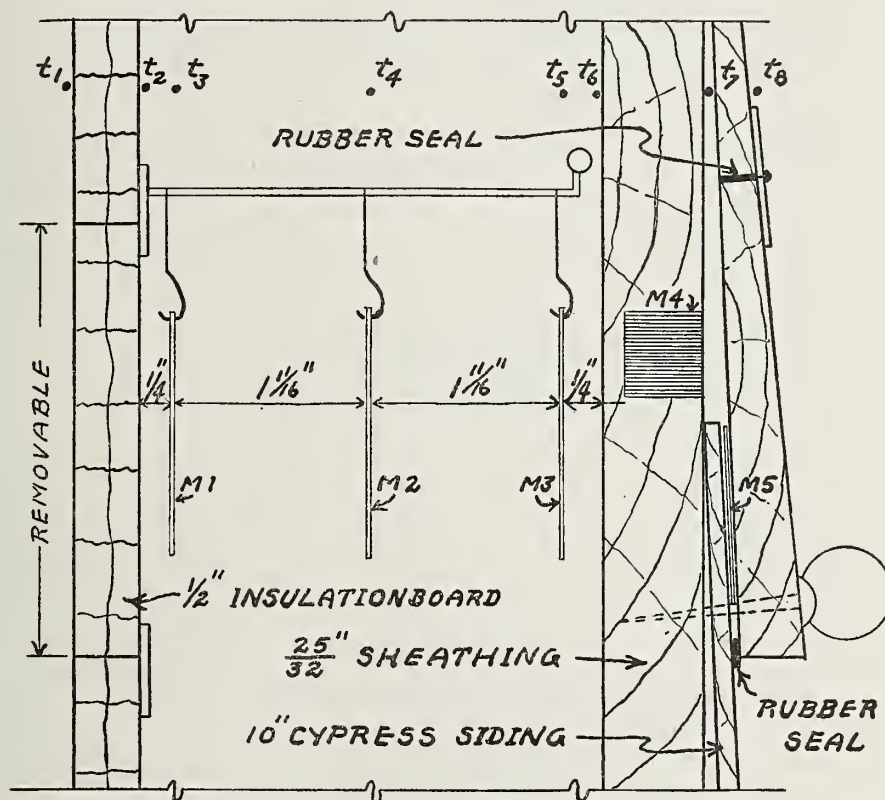


FIGURE 2.—Details of construction of test walls, showing locations where moisture and temperature determinations were made.

apparent average drop in vapor pressure across the walls from the inside to the outside was about 0.2 pound per square inch. This corresponds to the drop across walls in a colder climate with an inside humidity of approximately 50 percent, at 72° F, and outside temperatures of zero or below.

Data on the performance of the wall sections were obtained by making daily temperature and moisture determinations across each section. The readings were taken across each section of

thermocouples (t) and of the moisture samples (m) with respect to the cross section of the walls, and the method of construction to permit access to the moisture samples are shown in figure 2. The arrangement permitted the removal of the moisture specimens for weighing with a minimum of disturbance and, of course, temperature determinations were made without disturbing the wall. At the end of the 14-day period, the sections were opened and wet areas noted by inspection.

IV. PERFORMANCE OF TEST WALLS

Comparative average temperature distributions through the wall sections containing fiber sheathing boards and those containing wood sheathing are shown in figure 3. The spread between the two distributions across the air space between the studding represents

the beneficial effects of the higher insulation value of the fiber sheathing over that of the wood sheathing.

The average moisture conditions within the individual wall sections, and the observed condensation at the end of the 14 days' exposure, are shown in table 1.

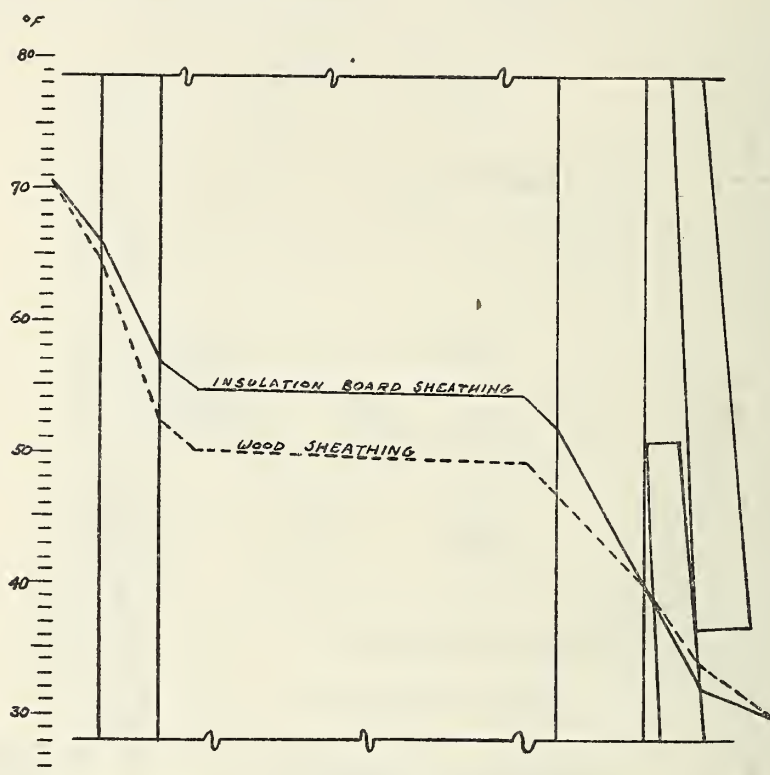


FIGURE 3.—Comparative temperature distributions through walls constructed with insulation sheathing and with wood sheathing.

TABLE 1.—Accumulation of moisture within test walls after 14 days' exposure ^a

Wall section	Kind of sheathing	Moisture-barrier location	Relative humidity of air in stud space	Moisture content of sheathing	Moisture content of siding	Condensation observed
A	Fiber	On warm side, under the wall board, on inside of studding	Percent 55	Percent 8.7	Percent 8.0	None.
B	do	Between studding and sheathing	100	8.3	7.1	On inside of vapor barrier.
C	do	None	93	14.9	167.5	On sheathing.
D	do	On cold side, under siding, on outside of sheathing	100	16.0	7.7	Do.
E	Wood	do	100	60.1	7.0	Do.
F	do	On both sides of sheathing	100	6.1	6.5	On inside of vapor barrier.
G	do	On warm side, under the wallboard, and on cold side, under siding	81	6.4	6.4	None.

^a The average inside conditions were 71° F and 70-percent relative humidity, and the mean outside temperature was 28° F.

There was no evidence of condensation or accumulation of moisture in section *A*, which had a vapor barrier on the warm side of the wall and none on the cold side. Hence, the performance of this section was considered completely satisfactory.

There was no condensation in wall section *G*. However, the humidity of the air within the stud space increased to 81 percent. It will be noted that the vapor barrier on the warm side of this wall was exactly like that used in section *A*. However, section *G* had a barrier of asphalt-duplex paper on the cold side of the wall, under the siding. The rise in the humidity of the air within the wall during the test indicates that, even with the best available barrier on the warm side of a wall, the use of a vapor barrier on the cold side, also, may cause some accumulation of moisture within the wall. The moisture doubtless enters the wall by leakage through the joints of the inside vapor barrier, as it is practically impossible to form a perfect seal over the entire wall, even when an impervious material is used.

Condensation of moisture occurred in all of the experimental wall sections except *A* and *G*. Thus, actual condensation took place in every instance where no vapor barrier was used on the warm side of the wall. In all instances where condensation did occur, the accumulation of moisture was greatest at the bottom of the walls, near the sills. The accumulation of moisture in this portion of a wall will in all probability result eventually in the decay of the sill and of the lower ends of the studding.

These results do not indicate that condensation or accumulation of moisture is essentially different in walls constructed with fiber sheathing than in those containing wood sheathing. Wood sheathing is more absorbent than the fiberboard, and the absorption of moisture from the warm side by wood sheathing might delay to some extent actual condensation. However, the moisture will probably do as much or more harm when absorbed by the sheathing as it would if it actually formed on its surface.

No effects of condensation or accumulation on the outside paint were noted, and it is as-

sumed that the test period was of too short duration for such effects. It may be assumed that an accumulation of moisture such as was noted in wall section *C* will eventually result in failure of the paint.

V. SUMMARY AND CONCLUSIONS

For walls of a frame house exposed to moderate winter weather in Washington, D. C., while moderately high humidity was maintained on the inside, a good vapor barrier on the warm side of the walls prevented condensation of moisture. The addition of a moisture-proof sheathing paper to the cold side of a wall tended to cause an accumulation of moisture between the walls even when an excellent barrier was used on the warm side.

There was no essential difference in this respect between the performance of walls of standard wood-frame construction and those sheathed with fiberboards. It is indicated, however, that a vapor seal should not be used on the cold side of outside walls if the inside air of a house is to be humidified. Hence, a sheathing that is highly impervious to vapor may tend to cause an accumulation of moisture.

It is essential that the moisture barrier on the warm side of the wall be continuous and unbroken, especially between floor levels, and at plumbing and electrical outlets, and other openings. Joints in the membrane serving as the vapor barrier should be over studs or over headers provided for the purpose. A lap of 2 inches or more is recommended for all joints.

VI. REFERENCES

- [1] H. W. Woolley, Moisture condensation in building walls, NBS Building Materials and Structures Report BMS63 (1940). 10¢.
- [2] L. V. Teesdale, Condensation in walls and attics, U. S. Department of Agriculture, Forest Service, Forest Products Laboratory, R1157.
- [3] F. S. Rowley, A. B. Algren, and C. E. Lund, Methods of moisture control and their application to building construction, University of Minnesota Bul. 17.
- [4] F. S. Rowley, A. B. Algren, and C. E. Lund, Condensation of moisture and its relation to building construction and operation, University of Minnesota Bul. 18.

WASHINGTON, August 5, 1942.

○

BUILDING MATERIALS AND STRUCTURES REPORTS

[Continued from cover page ii]

BMS32	Structural Properties of Two Brick-Concrete-Block Wall Constructions and a Concrete-Block Wall Construction Sponsored by the National Concrete Masonry Association	10¢
BMS33	Plastic Calking Materials	10¢
BMS34	Performance Test of Floor Coverings for Use in Low-Cost Housing: Part 1	10¢
BMS35	Stability of Sheathing Papers as Determined by Accelerated Aging	10¢
BMS36	Structural Properties of Wood-Frame Wall, Partition, Floor, and Roof Constructions with "Red Stripe" Lath Sponsored by The Weston Paper and Manufacturing Co.	10¢
BMS37	Structural Properties of "Palisade Homes" Constructions for Walls, Partitions, and Floors, Sponsored by Palisade Homes	10¢
BMS38	Structural Properties of Two "Dunstone" Wall Constructions Sponsored by the W. E. Dunn Manufacturing Co.	10¢
BMS39	Structural Properties of a Wall Construction of "Pfeifer Units" Sponsored by the Wisconsin Units Co.	10¢
BMS40	Structural Properties of a Wall Construction of "Knap Concrete Wall Units" Sponsored by Knap America, Inc.	10¢
BMS41	Effect of Heating and Cooling on the Permeability of Masonry Walls	10¢
BMS42	Structural Properties of Wood-Frame Wall and Partition Constructions with "Celotex" Insulating Boards Sponsored by The Celotex Corporation	15¢
BMS43	Performance Test of Floor Coverings for Use in Low-Cost Housing: Part 2	10¢
BMS44	Surface Treatment of Steel Prior to Painting	10¢
BMS45	Air Infiltration Through Windows	10¢
BMS46	Structural Properties of "Scot-Bilt" Prefabricated Sheet-Steel Constructions for Walls, Floors, and Roofs Sponsored by The Globe-Wernicke Co.	10¢
BMS47	Structural Properties of Prefabricated Wood-Frame Constructions for Walls, Partitions, and Floors Sponsored by American Houses, Inc.	10¢
BMS48	Structural Properties of "Precision-Built" Frame Wall and Partition Constructions Sponsored by the Homasote Co.	10¢
BMS49	Metallic Roofing for Low-Cost House Construction	10¢
BMS50	Stability of Fiber Building Boards as Determined by Accelerated Aging	10¢
BMS51	Structural Properties of "Tilecrete Type A" Floor Construction Sponsored by the Tilecrete Co.	10¢
BMS52	Effect of Ceiling Insulation Upon Summer Comfort	10¢
BMS53	Structural Properties of a Wall Construction of "Munlock Dry Wall Brick" Sponsored by the Munlock Engineering Co.	10¢
BMS54	Effect of Soot on the Rating of an Oil-Fired Heating Boiler	10¢
BMS55	Effects of Wetting and Drying on the Permeability of Masonry Walls	10¢
BMS56	A Survey of Humidities in Residences	10¢
BMS57	Roofing in the United States—Results of a Questionnaire	10¢
BMS58	Strength of Soft-Soldered Joints in Copper Tubing	10¢
BMS59	Properties of Adhesives for Floor Coverings	10¢
BMS60	Strength, Absorption, and Resistance to Laboratory Freezing and Thawing of Building Bricks Produced in the United States	15¢
BMS61	Structural Properties of Two Nonreinforced Monolithic Concrete Wall Constructions	10¢
BMS62	Structural Properties of a Precast Joist Concrete Floor Construction Sponsored by the Portland Cement Association	10¢
BMS63	Moisture Condensation in Building Walls	10¢
BMS64	Solar Heating of Various Surfaces	10¢
BMS65	Methods of Estimating Loads in Plumbing Systems	10¢
BMS66	Plumbing Manual	20¢
BMS67	Structural Properties of "Mu-Steel" Prefabricated Sheet-Steel Constructions for Walls, Partitions, Floor, and Roofs Sponsored by Herman A. Mugler	15¢
BMS68	Performance Test for Floor Coverings for Use in Low-Cost Housing: Part 3	15¢
BMS69	Stability of Fiber Sheathing Boards as Determined by Accelerated Aging	10¢
BMS70	Asphalt-Prepared Roll Roofings and Shingles	15¢
BMS71	Fire Tests of Wood- and Metal-Framed Partitions	20¢
BMS72	Structural Properties of "Precision-Built, Jr." Prefabricated Wood-Frame Wall Construction Sponsored by the Homasote Co.	10¢
BMS73	Indentation Characteristics of Floor Coverings	10¢
BMS74	Structural and Heat-Transfer Properties of "U. S. S. Panelbilt" Prefabricated Sheet-Steel Constructions for Walls, Partitions, and Roofs Sponsored by the Tennessee Coal, Iron & Railroad Co.	15¢
BMS75	Survey of Roofing Materials in the North Central States	15¢
BMS76	Effect of Outdoor Exposure on the Water Permeability of Masonry Walls	15¢
BMS77	Properties and Performance of Fiber Tile Boards	10¢
BMS78	Structural, Heat-Transfer, and Water-Permeability Properties of Five Earth-Wall Constructions	20¢
BMS79	Water-Distributing Systems for Buildings	15¢
BMS80	Performance Test of Floor Coverings for Use in Low-Cost Housing: Part 4	15¢
BMS81	Field Inspectors' Check List for Building Constructions (cloth cover, 5 x 7½ inches)	20¢
BMS82	Water Permeability of Walls Built of Masonry Units	20¢

[List continued on cover page iv]

BUILDING MATERIALS AND STRUCTURES REPORTS

[Continued from cover page iii]

BMS83	Strength of Sleeve Joints in Copper Tubing Made With Various Lead-Base Solders....	10¢
BMS84	Survey of Roofing Materials in the South Central States.....	15¢
BMS85	Dimensional Changes of Floor Coverings with Changes in Relative Humidity and Temperature.....	10¢
BMS86	Structural, Heat-Transfer, and Water-Permeability Properties of "Speedbrik" Wall Construction Sponsored by the General Shale Products Corporation.....	15¢
BMS87	A Method for Developing Specifications for Building Construction—Report of Subcommittee on Specifications of the Central Housing Committee on Research, Design, and Construction.....	10¢
BMS88	Recommended Building Code Requirements for New Dwelling Construction with Special Reference to War Housing.....	15¢
BMS89	Structural Properties of "Precision-Built, Jr." (Second Construction) Prefabricated Wood-Frame Wall Construction Sponsored by the Homasote Co.....	15¢
BMS90	Structural Properties of "PHC" Prefabricated Wood-Frame Constructions for Walls, Floors, and Roofs Sponsored by the PHC Housing Corporation.....	15¢
BMS91	A Glossary of Housing Terms.....	15¢
BMS92	Fire-Resistance Classifications of Building Constructions.....	25¢
BMS93	Accumulation of Moisture in Walls of Frame Construction During Winter Exposure....	10¢